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A Randomized Controlled Trial of Core Strengthening Exercises in U.S. Air Force Helicopter Crewmembers with Low Back Pain

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1. ABSTRACT

Background: The purpose of this study was to determine if five core strengthening exercises would decrease pain severity and related disability in U.S. Air Force helicopter aircrew members with low back pain.

Methods: The study was a randomized control group repeated measures design. The experimental manipulation consisted of a set of 5 core strengthening exercises performed 4 days a week for 12 weeks. Self-reported pain severity and disability were ascertained at baseline and 12 weeks using the Numerical Pain Rating Scale (NPRS) and Modified Oswestry Low Back Pain Disability Index (MODI), respectively. The NPRS was used to ascertain both daily pain (NPRS_{daily}) and inflight pain (NPRS_{flight}). Self-reported improvement or deterioration in low back pain was measured using the Global Rating of Change Scale (GRCS).

Results: Twelve participants were enrolled and 5 were randomized to the intervention group. The mean NPRS_{flight} score decreased 1.8 points versus increasing 0.1 points during the trial for the intervention and control groups, respectively. The mean MODI score decreased 4.8 points versus increasing 1.7 points during the trial for the intervention and control groups, respectively. The mean GRCS score at the end of the trial was 4.0 versus 0 for the intervention and control groups, respectively. There was no difference between groups in terms of mean NPRS_{daily} scores.

Conclusions: Core strengthening exercises were effective in reducing inflight pain and led to a reduction in pain symptoms and disability over the 12 week study period as compared to those participants who maintained their regular exercise regimen.

2. INTRODUCTION

The reported prevalence of lower back pain in helicopter aircrew members ranges from 51-92% as compared to 12-33% in the general population (18, 19). The greater prevalence of low back pain in helicopter aircrew members is hypothesized to result from the combination of ergonomic strain (i.e., poor posture) and exposure to vibration (19). The ergonomic layout of helicopter controls leads pilots to adopt a posture in which the torso is forward flexed and tilted to the left. This body position creates the most risk for back problems when coupled with exposure to seated vibration (9).

Helicopter aircrew members are exposed to vertical whole-body vibration at the principal resonance frequency of the upper body (i.e., 5 Hz). Extended exposure to this vibration frequency may result in muscle fatigue and vibro-creep, the latter involving load-induced distortion of tissues that remains once the load has been removed. These vibration induced changes to the spine are associated with an increased likelihood for degenerative changes. Although there may be instances when degenerative change in the spine does not lead to low back pain, degenerative changes in the spine tend to be the primary source of pain symptoms (20).

While helicopter aircrew members are at increased risk for back pain, direct mitigation of the purported injurious ergonomic and vibratory exposures is unlikely given the need for substantial design enhancements to existing aircraft (19). Consequently, non-materiel mitigations are required in the near term, if not longer. It is known that individuals suffering from back pain generally lose stiffness between spinal motion segments, the latter resulting in a decreased tolerance to externally-generated spinal loads. However, pain may be reduced if the individual is able to train muscular motor patterns to increase spinal stability and restrain aberrant micromotion (10). Additionally, specific exercises that build core body strength have been shown to reduce pain in chronic low back pain patients (15, 17). The purpose of this study was to determine if five core strength exercises would mitigate pain severity and related disability in U.S. Air Force helicopter aircrew members with low back pain. The following research hypotheses were adopted for the present study:

- *H1*: Mean self-reported pain severity levels will be less for helicopter aircrew members with low back pain performing core strengthening exercises as compared to controls.
- *H2*: Mean self-reported disability levels will be less for helicopter aircrew members with low back pain performing core strengthening exercises as compared to controls.
- *H3*: Mean improvement in pain symptoms will be greater for helicopter aircrew members with low pain back performing core strengthening exercise as compared to controls.
- *H4*: The proportion not achieving a minimal important clinical difference in pain severity level and disability level over 3 months will be lower for helicopter aircrew members with low back pain performing core strengthening exercise versus controls.

3. METHODS

Institutional Review

The study was conducted under a human-use protocol approved by the 711th Human Performance Wing Institutional Review Board and in accordance with Federal and USAF regulations on the protection of human participants in biomedical and behavioral research.

Participants

The participants were active Air Force helicopter aircrew members assigned to Air Force Global Strike Command, Air Combat Command, Air Force District of Washington, Pacific Air Forces, and U.S. Air Forces in Europe during the period from July 2012 to September 2013 who responded to an electronic solicitation for volunteers for a study investigating the effect of exercises in helicopter aircrew members experiencing low back pain. The study inclusion criteria was an active duty helicopter aircrew member with ≥ 4 weeks of self-reported low back pain who was currently flying ≥ 1 hour/week. Study exclusion criterion included: 1) history of low back pain attributable to a traumatic event; 2) history of preexisting low back pain prior to exposure to the helicopter work environment; 3) chronic lower extremity radicular symptoms below the knee; 4) chiropractic manipulation therapy, physical therapy, or acupuncture within the prior four weeks; 5) current medical restriction from performing flying duties; and 6) currently pregnant.

Study Design and Experimental Manipulation

The study used a randomized control group repeated measures design. The experimental manipulation consisted of a set of 5 core strengthening exercises chosen by the physical therapist member of the study team (L.C) and described by Childs and colleagues (4) Liebenson (15): supine with bilateral upper extremity and lower extremity lifts (modified deadbug), supine curl-up, quadruped with alternate upper extremity and lower extremity lift, horizontal side support, and prone with bilateral upper extremity and lower extremity lift (modified superman) (Figure 1). One set of 12 repetitions of each of the 5 exercises was performed on any 4 days in a week for 12 weeks. The experimental manipulation was thus comprised of 48 exercise sessions performed during a 3 month period. The control condition was continuation of the participant's pre-study exercise regimen. Outcome measures were assessed at baseline and 12 weeks.

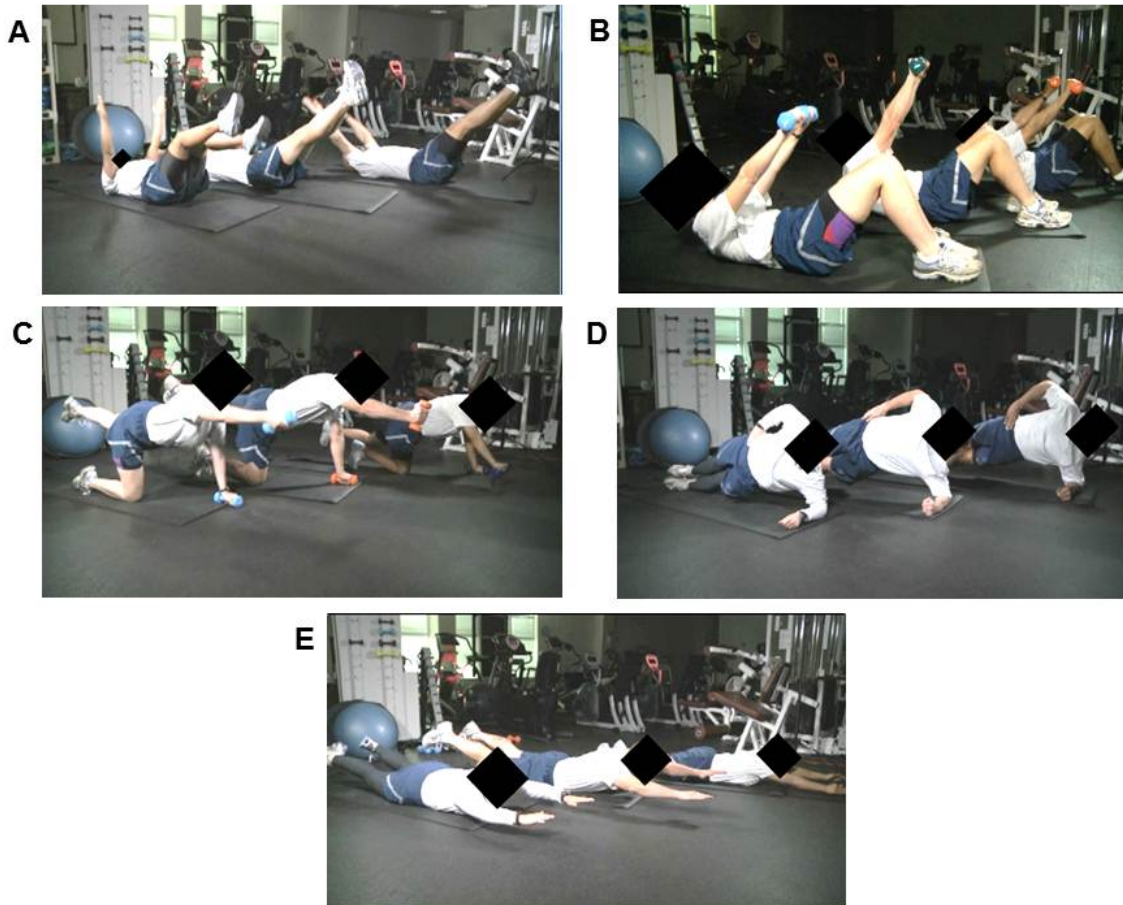


Figure 1. Five core strengthening exercises comprising the experimental manipulation: supine with bilateral upper extremity and lower extremity lifts (modified deadbug) [A], supine curl-up [B], quadruped with alternate upper extremity and lower extremity lift [C], horizontal side support [D], and prone with bilateral upper extremity and lower extremity lift (modified superman) [E].

Instruments

Initial Study Questionnaire: The initial study questionnaire was comprised of 27 items. Five items addressed basic demographic information: age, gender, rank, height, and weight. Four items inquired about the type (i.e., cigarettes, cigars, chewing tobacco, other tobacco products) and quantity of tobacco use. Six items characterized participants' aviation experience and exposure to the helicopter work environment: total flight hours, total helicopter flight hours, average monthly helicopter flight hours, percentage of missions greater than 4 hours ($\leq 10\%$, 10-25%, 25-50%, 50-75%, 75-100%), crew position (pilot, flight engineer, gunner, other), and primary helicopter model (UH-1, HH-60, other). One dichotomous item was an indicator for

recurring exposure to the helicopter work environment: “do you currently fly helicopters at least one hour per week?” Four items characterized whether participants ever experienced pain or discomfort in the lower back, upper back/shoulders, neck, and/or thighs that was self-attributed to exposure to the helicopter work environment; for positive responses, participants were queried about the frequency and intensity using a Likert-type scale. Seven dichotomous items identified participants with: residual pain or discomfort after performing flight duties and whether this pain or discomfort impacted participants’ ability to perform flight duties; currently experiencing low back pain of four or more weeks in duration; continuous lower extremity sensory symptoms; lower extremity symptoms attributed to exposure to the helicopter work environment; a history of involvement in a helicopter mishap requiring medical treatment; and use of non-pharmacological interventions (acupuncture, chiropractor, physical therapy, and/or spinal injections) to control pain symptoms.

Pain Evaluations: Self-reported pain severity was ascertained using the Numerical Pain Rating Scale (NPRS). The NPRS asks participants to rate their current pain intensity from 0 (“no pain”) to 10 (“worst possible pain”). The NPRS is ubiquitous as a screener in many health care environments and has been validated as a measure of pain intensity in populations with known pain (5, 12). One NPRS score was computed for daily activity (NPRS_{daily}) and one NPRS score was specifically related to flight (NPRS_{flight}). Self-reported improvement or deterioration in low back pain was measured using the Global Rating of Change Scale (GRCS) (7). The GRCS asks participants to rate the change in their symptoms. The GRCS has 15 possible choices ranging from 7 (“a very great deal better”) to -7 (“a very great deal worse”), with 0 representing no change. The GRCS has been used to effectively monitor symptom progression in patients with painful disorders (5).

Disability Evaluation: The impact of low back pain on everyday activities was assessed using the Modified Oswestry Low Back Pain Disability Index (MODI). The MODI consists of 10-items addressing the following considerations: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, social life, traveling, and changing degree of pain. For each item, the participant selects only one response from six choices. Each of the 10 items is scored separately (0 to 5 points each) and then added up (max total = 50 points) (6).

Procedure

An informational e-mail message was sent to helicopter aircrew members in the aforementioned organizations explaining the general nature of the study, the voluntary nature of participation, and instructions for participating. Helicopter aircrew members who volunteered to enroll in the study were asked to attend a 20 minute briefing with the principal investigator. At a participant’s location, a local representative, who was not part of the research team, assisted the principal investigator by facilitating the study recruitment briefing via teleconference. The

principal investigator described the study and answered participant questions. The local representative then provided the participant with the informed consent document (ICD), allowing them to review it while the principal investigator was on the phone. The local representative witnessed the participant sign the ICD and e-mailed the ICD to the principal investigator. Upon receipt of the signed ICD, each participant was e-mailed the URL for the electronic study questionnaire. Participants who met study inclusion criteria were then medically cleared by their local flight surgeon for involvement in the study based on a medical record review and were then subsequently randomized to either the experimental or control group.

Participants in the experimental group were mailed an exercise DVD with the five core strengthening exercises. They were instructed to follow the DVD to ensure correct and safe execution of the core strengthening exercises. They also maintained an exercise log that was sent weekly to the principal investigator. Participants in both the experimental and control groups accomplished the NPRS and MODI at baseline and the NPRS, GRCS, and MODI at 12 weeks. Participants were asked to provide pain ratings using the NPRS for both “daily pain” and “pain experienced in flight.” Any participant unable to complete at least 8 of the 48 exercise periods in a 3 month period was either requested to restart the protocol or be disqualified from the study if unable to complete the protocol in 6 months.

Statistical Analysis

The dependent variables used to measure pain included scores of the NPRS and the GRCS. The dependent variable used to measure disability was the MODI. A dichotomous variable denoting group membership (intervention or control) was the primary independent variable.

Descriptive statistics were computed for all study variables and intervention and control groups compared at baseline. Categorical variables were summarized using frequencies and percentages. Continuous variables that were normally distributed were summarized using the mean and standard deviation and continuous variables that were not normally distributed were summarized using the median and range. Categorical baseline characteristics, where appropriate, were compared between the treatment groups using Fisher’s exact test whereas differences between treatment groups for the continuous variables were tested using a *t*-test for the normally distributed variables and a median test for variables non-normally distributed.

To determine whether or not the experimental manipulation had a significant impact on pain and disability, comparisons were made between the intervention and control groups with respect to scores on the NPRS_{daily}, NPRS_{flight}, and MODI at baseline and 12-weeks and GRCS score at 12 weeks. A repeated measure ANOVA was used to test for an interaction effect of group with time for NPRS and MODI scores. Simple *t*-tests were used to examine the change in

response score from baseline to 12 weeks. The GRCS score between the intervention and control group was compared at 12 weeks using a nonparametric test on the median since this response was not normally distributed. Response variables were also compared using the Minimal Clinically Important Difference (MCID). The MCID was conservatively defined to be a change of -2 for the NPRS (11), -6 for the MODI (10), and +3 for the GRCS (5). All analyses were conducted using SAS version 9.3 software and the level of significance was set to 0.05.

4. RESULTS

Demographics

Thirteen participants, all male, were enrolled in the study. Of these, 6 were randomly assigned to the intervention group and 7 were assigned to the control group. One participant in the intervention group was lost to follow-up (i.e., baseline data only); this participant did not differ in demographic characteristics from those participants who completed the study. Participants' responses on the pre-study questionnaire and survey instruments are summarized in Table 1. Only 3 participants (1 in the intervention group and 2 in the control group) were taking medications; reported medications included acetaminophen, celecoxib, esomeprazole, ibuprofen, levothyroxine, losartan, and simvastatin. Only one participant in the control group reported the use of tobacco products (1 dip per day). Half the participants were pilots, and gunners and flight engineers each comprised one quarter of the participants; this distribution of crew positions was similar across both groups. All participants reported satisfaction with their job. No participants reported any Duties Not Including Flying (DNIF) days or other days of restricted duty attributable to low back pain; four participants reported restricted duty attributable to other reasons (1 in the intervention group and three in the control group). Overall, there were no observed significant differences between the intervention and control groups. Based on the exercise logbooks, it was determined that all participants in the intervention group completed the 48 exercise sessions (i.e., 4 sessions per week for 12 weeks).

Table 1. Baseline characteristics and comparisons by group.

Characteristic	Intervention (N = 5)	Control (N = 7)	P-value
Age (yrs), median (range)	31 (28-33)	26 (25-45)	0.219
Height (in), median (range)	72 (70-72)	71.0 (69-76)	0.575
Weight (lbs), mean (std)	191.0 (19.5)	174.9 (14.7)	0.131
BMI (kg/m ²), mean (std)	26.3 (2.4)	23.8 (1.6)	0.052
Time in service (yrs), median (range)	9 (5-13)	6 (2-21)	0.575
Total flight hours, mean (std)	1069.0 (553.4)	1062.8 (676.5)	0.987
Total helicopter flight hours, mean (std)	909.0 (511.8)	992.7 (696.6)	0.825
30-d helicopter flight hours, mean (std)	26.8 (15.2)	19.7 (15.7)	0.457
60-d helicopter flight hours, mean (std)	49.2 (20.1)	41.5 (29.0)	0.623
90-d helicopter flight hours, mean (std)	87.4 (34.0)	64.2 (35.9)	0.286
Low back pain onset age (yrs), mean (std)	26.0 (1.6)	26.3 (4.5)	0.896
NPRS _{daily} score, median (range)	3 (3-4)	3 (2-6)	0.896
NPRS _{flight} score, mean (std)	4.4 (1.1)	3.4 (1.4)	0.231
MODI score, median (range)	8 (0-22)	6 (2-22)	0.093

BMI = body mass index, MODI = Modified Oswestry Low Back Pain Disability Index, NPRS_{daily} = Numerical Pain Rating Scale with respect to daily activity, NPRS_{flight} = Numerical Pain Rating Scale with respect to the flight environment, std = standard deviation.

Pain severity

Figure 1A-B displays the ANOVA model estimated least-square means and standard errors for NPRS_{daily} and NPRS_{flight}, respectively, by group and time. The results of the ANOVA models for both NPRS_{daily} and NPRS_{flight} partially support Hypothesis 1. For the NPRS_{daily} model, there was no significant interaction effect between group and time ($F_{3,10} = 2.26$, $P = 0.144$). For the NPRS_{flight} model, however, there was a significant interaction effect ($F_{3,10} = 2.76$, $P = 0.020$); the mean NPRS_{flight} score decreased by about 1.8 points on average over the 12 week period for the intervention group ($t_{10} = 2.46$, $P = 0.034$, $\eta^2 = 2.46$) versus an increase of 0.7 points for the control group (n.s., $t_{10} = -1.26$, $P = 0.235$).

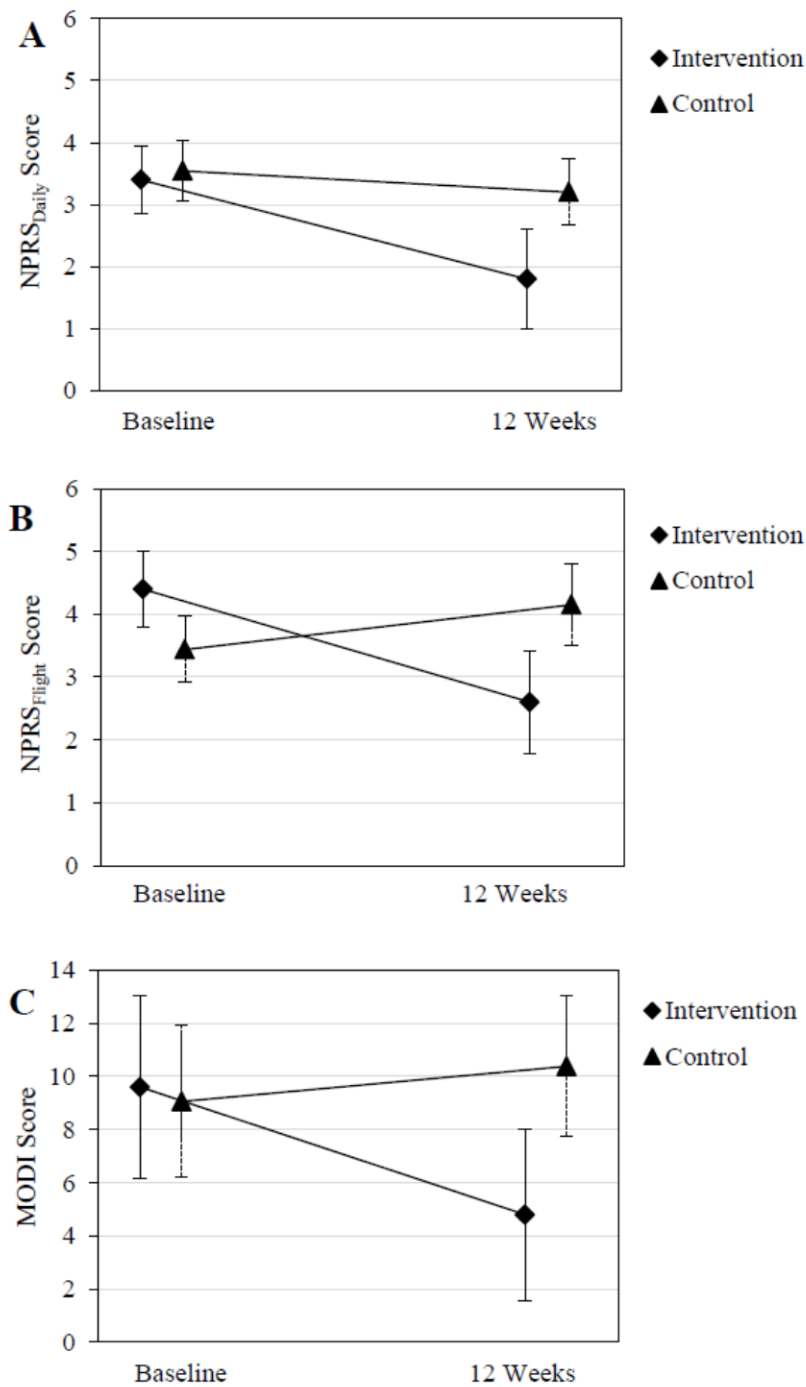


Figure 2. ANOVA model estimated least-square means and standard errors for Numerical Pain Rating Scale score with respect to daily activity (NPRS_{daily}) [A], Numerical Pain Rating Scale score with respect to the flight environment (NPRS_{flight}) [B], and Modified Oswestry Low Back Pain Disability Index score (MODI) [C].

Disability

Figure 1C displays the ANOVA model estimated least-square means and standard errors for MODI score by group and time. The results of the ANOVA model support Hypothesis 2. There was a significant interaction effect between group and time effect ($F_{3,10} = 3.75$, $P = 0.049$). Comparing baseline to the end of the study period, the mean MODI score decreased by about 4.8 points on average for the intervention group ($t_{10} = 2.62$, $P = 0.026$, $\eta^2 = 2.62$); in contrast, the mean MODI score increased by 1.7 points in the control group (n.s. , $t_{10} = -1.11$, $P = 0.295$).

Global Rating of Change

There was a significant difference between the median GRCS scores of the intervention and control groups at 12 weeks ($P = 0.006$). Median reported GRCS for the intervention group was 4.0, with a range from 0 to 5 indicating that, in general, these participants reported improvements in symptoms. However, the median reported GRCS for the control group was a 0 and ranged from -4 to 0 indicating at best that these participants experienced no change, though some experienced a worsening of symptoms. The results of this nonparametric test support Hypothesis 3.

Minimal Important Clinical Difference

For all measures of pain severity and disability, there were more participants failing to achieve the MCID in the control group as compared to the intervention group (Table 2). There were significant differences in the proportion of those experiencing a MCID for NPRS_{flight} score ($P = 0.046$) and GRCS score ($P = 0.010$). These results partially support Hypothesis 4.

Table 2. Number of participants achieving minimal important clinical difference on response variables by 12 weeks.

Response Variable	Minimal Important Clinical Difference		<i>P</i> -value
	Yes	No	
NPRS _{daily}			
Intervention	3	2	0.222
Control	1	6	
NPRS _{flight}			
Intervention	3	2	0.046
Control	0	7	
GRCS			
Intervention	4	1	0.010
Control	0	7	
MODI			
Intervention	3	2	0.061
Control	0	6	

GRCS = Global Rating of Change Scale, MODI = Modified Oswestry Low Back Pain Disability Index, NPRS_{daily} = Numerical Pain Rating Scale with respect to daily activity, NPRS_{flight} = Numerical Pain Rating Scale with respect to the flight environment.

5. DISCUSSION

Low back pain in helicopter aircrew members has been investigated since the 1960s. This literature has assessed the prevalence of low back pain in helicopter aircrew members and identified vibration and poor inflight posture as contributing factors (19). More recently, helicopter aircrew members have had to contend with new aircraft and improvements to legacy aircraft that introduce new vibration concerns (21). Additional aircrew equipment, such as body armor, survival vests, and night vision devices, augment the weight applied to musculature already stressed by vibration and poor inflight posture. This additional equipment, coupled with increased mission durations, has exacerbated perceived low back pain in helicopter aircrew members (13, 16). The resultant outcome is that helicopter aircrew members are at elevated risk for acute low back pain that can decrease human performance because of reduced concentration and hurrying of key tasks (1, 22); and acute pain over time may yield chronic pain and disability (2).

Researchers have concluded that the best solution is new seats that alleviate ergonomic stresses resulting from poor inflight posture and isolate crewmembers from vibration (3, 19). However, redesigning the seating arrangements of helicopter aircrew members may not be practical from a financial perspective and so other solutions are needed (19). Proposed interim measures include a variety of low back pain mitigating interventions to the existing seating arrangements. Lumbar supports (3, 13) and seat cushions that attenuate vibrations (13, 19) have been demonstrated to be effective tools. Unfortunately, fielding this equipment to helicopter aircrew members, and then replacing the equipment when it no longer provides support, has proven challenging (8, 13). For example, the Kadix Business Case Analysis (13) of over 1,700 helicopter aircrew members found that current lumbar support, if existent, does not adequately address ergonomic needs and recommended that supplemental seat support aids be fast tracked for evaluation and deployment.

Another approach to interventions is to modify the helicopter aircrew member rather than the equipment (19). This approach, which can be taken in conjunction with modifications to the seating arrangement such as lumbar supports and seat cushions, involves core strengthening exercises as investigated in the present study. Despite the small sample size, the present study demonstrated that core strengthening exercises were effective in reducing inflight pain and led to a reduction in symptoms and disability over the 12 week study period as compared to those participants who maintained their regular exercise regimen. These results are consistent with the findings of a systematic literature review of randomized controlled trials (RCTs) investigating exercise interventions for treatment of chronic low back pain; a total of 16 RCTs involving 1,730 patients were included in this review and exercises were shown to have a positive effect in all 16 trials (12 of the 16 trials specifically incorporated strengthening exercises) (14).

Study Limitations

The primary study limitation was the small sample size. It was originally calculated, assuming a strong correlation between observations (the most conservative case), that a sample size of $n = 42$ per group for the NPRS, $n = 75$ per group for the MODI, and $n = 12$ per group for the GRCS would result in 80% power to detect the specified MCIDs at an alpha of 0.05. However, the observed variability in the study was only about half of that which was planned in the original analysis. Thus, although the desired group sizes were not achieved in the study, it was arguably not to the overall detriment of the study with respect to detectable differences. Nonetheless, the results of this study should be verified in a larger sample as it is possible that the small number of participants may not be representative of the overall population of helicopter aircrew members with low back pain (i.e., the question of external validity). Additionally, the participants in this study were very compliant in accomplishing the prescribed exercises; it remains to be seen if the efficacy of the exercise intervention holds when participants are not being monitored for compliance.

Suggestions for Future Research

In addition to validating the findings of this study in a larger sample, future research should look at the relative efficacy of co-interventions in mitigating low back pain and follow participants for a longer period of time to evaluate the durability of the observed improvements in pain and disability. Another avenue of investigation is to evaluate the value of core strengthening exercises on the prevention of low back pain versus the mitigation of existing low back pain in helicopter aircrew members.

Summary

The results of this present study, which involve a small number of participants, nonetheless demonstrated that core strengthening exercises had a positive impact on perceived pain and disability in helicopter aircrew members with low back pain. Together with other co-interventions, such as lumbar supports and vibration attenuating seat cushions, helicopter aircrew members may be able to mitigate the adverse effects of vibration and poor inflight posture pending a more permanent solution involving redesign of their seating arrangements.

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APPENDIX 1: ACRONYMS

ANOVA	Analysis of Variance
BMI	Body Mass Index
DNIF	Duties Not Including Flying
DTIC	Defense Technical Information Center
DVD	Digital Video Disc
GRCS	Global Rating of Change Scale
ICD	Informed Consent Document
MCID	Minimal Clinically Important Difference
MODI	Modified Oswestry Low Back Pain Disability Index
NPRS	Numerical Pain Rating Scale
URL	Uniform Resource Locator